STATE OF CALIFORNIA
HIGHWAY TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

AN EVALUATION OF BANDS USED TO COUPLE CORRUGATED METAL PIPE

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MATERIALS & RESEARCH DEPARTMENT

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

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Dear Sir:

Submitted for your consideration is a report of:

AN EVALUATION OF BANDS

USED TO COUPLE

CORRUGATED METAL PIPE

Study made by . . . . Structural Materials Section
Under direction of . . . . E. F. Nordlin
Work supervised by . . . . J. R. Stoker
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Report prepared by . . . . J. R. Stoker and G. W. Mann

Very truly yours,

Eric F. Nordlin

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Attach.

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I. PREFACE

The requirements for coupling bands for use with corrugated metal (steel) pipe are established by AASHO Designation: M36. This specification is as follows:

> "Field joints shall be made with bands of the same base metal as the culverts. The bands shall be not less than 7 inches wide for diameters of 8 inches to 30 inches inclusive; not less than 12 inches wide for culverts with diameters 36 inches to 60 inches inclusive; and not less than 24 inches wide for culverts with diameters greater than 60 inches. Such bands shall be so constructed as to lap on an equal portion of each of the culvert sections to be connected, and preferably shall be connected at the ends by galvanized angles having minimum dimensions of 2 inches by 2 inches by 3/16 inch. The 7 inch band shall have at least two galvanized bolts not less than 1/2 inch diameter. The 12 inch band shall have three and the 24 inch band shall have five 1/2 inch bolts. Other equally effective methods of connecting the pipe sections may be used if approved by the Engineer. Coupling bands may be not over two numerical thicknesses lighter than that used for the pipe but not less than 0.052 inches thick."

Compliance to the above specification is required by the State of California Standard Specifications for all corrugated metal pipe installations with the exception that the minimum gage of sheet allowed is 16 gage (0.0598 inches).

The following is a resumè of coupling bands presently being furnished to state highway contracts which have been considered to comply with the requirements of the California Division of Highways specifications and AASHO Designation: M36, either per se or as "other equally effective methods of connecting the pipe sections":

1. A two piece integral flange die formed band, helically corrugated to match the connected pipe. The ends of both pieces are flattened out to form matching flanges. These flanges are joined by four 3/8-inch galvanized bolts. The band is 7 inches wide and is used on 6, 8, and 10 inch helically corrugated lockseam pipe. Based on laboratory tests (Ref. 1), this coupler with the 3/8-inch bolts is considered acceptable for use on this small diameter of pipe provided a cut washer is placed under the nut (see Figure 2).

2. A two piece helically corrugated band connected at the ends by lugs, formed by slitting a portion

of the band and punching out a section of the sheet to form the lug. This band is 12 inches wide and is connected by four 1/2-inch bolts which are oriented parallel to the corrugation. The bolts have specially formed heads and washers which fit the corrugation profile. This band has been approved for use for coupling helically corrugated lockseam pipe in sizes of 12 through 24 inch (see Figure 3).

Although the above is being furnished as a two piece band, a one piece band of this type would be acceptable provided it could be properly installed in the field.

3. A one or two piece helically corrugated band connected at the ends by 2 inch by 2 inch by 3/16-inch angles either spot welded or riveted to the band. The angles are either oriented normal to the corrugations or parallel to the axis of the pipe. Where the angles are placed parallel to the pipe, the bolt holes are slotted longitudinally to allow adjustment of the ends of the band which is necessary due to the helix angle. This band is 12 inches wide for all sizes of helically corrugated lockseam allowed by our specifications and is approved for use for pipes in diameters of 12" through 48". The band is connected by three 1/2-inch bolts per pair of angles (see Figure 4).

4. All sizes of annularly corrugated pipe are connected by bands utilizing angles as per AASHO M36 specifications (see Figure 5).

II. INTRODUCTION

The purpose of this investigation is twofold: to present a summary of coupling bands which are already considered to comply with the specifications (see Preface), and to evaluate the performance of two new types of coupling bands for use in joining corrugated metal pipe. These new types of bands have been submitted by their manufacturers to determine their acceptability for use on state contracts.

The first type submitted is proposed for use on annularly corrugated pipe. This band is a one piece annularly corrugated band connected at the ends by lugs, formed by slitting a portion of the band and punching out a section of the sheet to form a lug. The principle is identical to that used on a helically corrugated band discussed in the Preface. The band is connected by two 1/2-inch bolts with specially formed heads and washers which fit the corrugation. This coupling band was submitted in two widths, one 7 inches wide and containing 3 corrugations; the other about 9-1/2 inches wide and containing 4 corrugations. The couplings submitted were made from 16 gage sheet and were fabricated for 18 inch pipe (see Figures 7 and 9).

The second type of coupling band submitted is proposed for use as a universal coupling band which can connect annularly corrugated pipe, helically corrugated pipe, or a combination of the two. The band is a one piece band formed from galvanized steel culvert sheet with dimples impressed in the sheet in circumferential rows and connected at the ends by 2 inch by 2 inch by 3/16-inch angles. Three 1/2-inch bolts are used to connect the band. The dimples are of such configuration as to nest in the corrugations of the pipe. A cross section taken through the center of the dimple matches the cross section of the corrugation. The dimples are spaced circumferentially in such a manner that each corrugation of a helically corrugated pipe will contain a dimple when coupled with this band. The coupling bands submitted for evaluation were 14 inches wide, contained two circumferential rows of dimples, and were fabricated from 16 gage sheet. They were made for 18 inch pipe. The rows of dimples were spaced 7 inches apart and each row contained 8 dimples at 7 inch centers (see Figure 10).

To evaluate the new coupling bands, flexural bend tests were performed on coupled lengths of 16 gage 18-inch diameter corrugated metal pipe. Two types of bands already considered acceptable for use were also tested for comparison. They were (1) a 16 gage, 7 inch wide one piece annular corrugated band with angles fastened by rivets or spot welding and connected by two 1/2-inch bolts (Figure 5) and (2) a 16 gage, 12 inch wide two piece helically corrugated band connected by four 1/2-inch bolts through formed lugs (Figure 3).

III. SUMMARY

The different types of coupling bands were compared by a third-point flexural load test of equal spans of coupled 18-inch 16 gage pipe (see Figure 1). The applied loads were recorded from the testing machine. The deflection at midspan and the extension of the lower surface of the coupled pipe at the joint were simultaneously recorded (see Tabulated Values in Appendix). All coupling bands were fabricated from 16 gage steel and were connected with 1/2-inch bolts.

Two 7-inch wide coupling bands utilizing angles and connecting bolts were tested as couplers for annularly corrugated metal pipe (see Figures 5 and 6). These are the standard AASHO coupling bands. A test was run on each coupling band with the angles positioned on the bottom or tension side of the connected pipe; the test was repeated with the angles located on the side or neutral axis of the pipe to determine if the angle location affected the ultimate load capacity of the coupled pipe. The effect noted from the test positioning of the angles was negligible. One coupler furnished for testing had a distorted angle as a result of mishandling (see Figure 6). The ultimate load capability of this coupler was significantly lower than the results obtained for the other coupler. The minimum ultimate load sustained by pipe joined by these couplers was 3540 pounds and 6700 pounds respectively.

A two piece 12 inch wide helically corrugated coupling band connected by bolts through formed lugs was used to join lengths of helically corrugated lockseam pipe (see Figure 3). The pipe thus connected sustained an ultimate flexure load of 8400 pounds. Failure occurred by compression buckling of the upper surface of the pipe with the coupler remaining intact with the pipe. The coupler was therefore able to develop the flexural strength of the pipe.

Tests performed on annular corrugated metal pipe connected by a 7 inch wide coupling band (see Figure 7) connected by bolts through formed lugs resulted in a minimum ultimate load of 7740 pounds as compared to the ultimate load of 6700 pounds on the forementioned "Standard AASHO" coupler. A subsequent test on an intentionally damaged coupling band as could occur through the weakened plane of the band at the connecting lugs resulted in an ultimate flexural load of 5300 pounds (see Figure 8).

Tests on coupling bands similar to the above but about 9-1/2 inches wide and lapping an extra corrugation on one side of the joint produced a minimum ultimate load of 6800 pounds (see Figure 9). All samples of this proposed coupling band produced equal or greater load carrying capacity as compared to the standard AASHO coupling band.

Tests performed on pipe coupled with the universal or dimpled coupling yielded ultimate loads at least 10% greater than the 7-inch wide AASHO coupler (see Figures 10 and 11). Tests were performed on connected pipe as follows: annular to annular, annular to helical, and helical to helical. The minimum load experienced was with annular to helical corrugated metal pipe. This load was 7600 pounds.

IV. CONCLUSIONS

Based on the several flexural load tests performed on 18-inch coupled corrugated metal pipe, the following conclusions relative to the various type coupling bands can be drawn:

1. A significant reduction in joint efficiency can occur as a result of the following:

    a. Coupling bands connected by angles which are improperly fabricated or damaged, or improperly installed.

    b. The incorrect use of coupling bands which are not fabricated to fit the pipe being connected.

2. Coupling bands utilizing angles which are spot welded to the band appear to have an advantage over angles which are riveted to the band as there is no interference as occurs with a raised rivet head.

3. The annularly corrugated coupling band, having a nominal width of 7-inches and connected by bolts through formed lugs in the ends of the band, produces a stronger joint than the "standard" AASHO band utilizing angles. However, due to the required slitting of the band material to form the fastening lugs, there is concern that the remaining material between the two lugs on this narrow band may fail during installation or as a result of corrosion and service loads imposed on the coupler. Such a failure can drastically reduce the joint efficiency.

4. The annularly corrugated coupling band, having a nominal width of 9-2/3 inches and connected by bolts through formed lugs in the ends of the band, is equivalent in joint strength to the standard AASHO coupling band. Due to the extra width of the band, there is little likelihood of a tearing failure occurring at the ends of the band due to the required slitting of the sheet to form the connecting lugs. The possibility of this type of failure exists with the 7-inch band discussed in Item #3 above.

5. The two piece 12-inch wide helically corrugated band, which is connected by bolts through formed lugs in the ends of band pieces, is capable of developing the strength of the pipe.

6. The universal or dimpled band in the 14-inch width as tested is an effective device for connecting any

type of corrugated metal pipe fabricated with the standard 2-2/3 inch by 1/2-inch corrugation. It possesses equal or superior joint strength as provided by the standard AASHO coupling band and is simple to install on the pipe. This band also allows greater flexibility of the pipe joint for a given load than the standard band without allowing the joined pipe to separate.

Present California Division of Highways Standard Specifications require that the inside diameter of the pipe shall not vary more than one percent or 1/2-inch, whichever is greater, from the nominal diameter. This may not be a restrictive enough tolerance from the standpoint of tight fit for the dimpled coupling band, particularly where the coupling of two small diameter lengths of helical pipe, with diameters 1/2-inch apart, is involved.

V. RECOMMENDATIONS

Based on the results of this series of tests and past laboratory tests on coupling bands (see Ref. 1), recommendations regarding the acceptability of various forms of coupling bands used to join helical or annular corrugated metal (steel) pipe are made herein.

1. The 7-inch wide, two piece, helically corrugated, integral flange, die formed band connected by 4-3/8-inch galvanized bolts with cut washers under the nuts is an acceptable coupling band for joining helically corrugated lockseam pipe in sizes of 6, 8, and 10-inch diameter (see Figure 2).

2. A one or two piece helically corrugated band 12-inches in width and connected by 2- 1/2-inch bolts per connection through integral formed lugs is an acceptable coupling band for joining helically corrugated lockseam pipe in sizes of from 12-inches to 30-inches inclusive. The connecting lugs shall be separated by one full corrugation. The bolt heads and cut washers required under the nuts shall be shaped to fit the corrugation (see Figure 3).

3. A one or two piece helically corrugated band 12-inches in width and connected at the ends by 2-inch by 2-inch by 3/16-inch angles either spot welded or riveted to the band is an acceptable coupling band for all sizes of helically corrugated lockseam pipe allowed by the specifications, viz. 6-inch through 48-inch. Three 1/2-inch bolts are required per pair of angles for pipe diameters greater than 30-inches. The connecting angles may be placed normal to the corrugations or parallel to the axis of the pipe. If placed parallel, the holes in the outstanding legs shall be slotted longitudinally a sufficient amount to allow adjustment of the band to correct for the helix angle (see Figure 4).

4. The 7-inch wide annularly corrugated coupling band utilizing integral formed connection lugs is considered a questionable coupler due to the possibility of a material failure occurring parallel to and between the lugs. Acceptance of this coupling band is not recommended.

5. The nominal 9-2/3 inch wide annularly corrugated coupling band utilizing integral formed connection lugs connected by 2-1/2 inch bolts is an acceptable coupler for connecting corrugated metal pipe in all

sizes up to 30-inches inclusive. The bolt heads and cut washers required under the nuts shall be shaped to fit the corrugation. The connecting lugs shall be separated by one full corrugation. The coupling band shall be not less than 9-2/3 inches wide (see Figure 9).

6. The universal or dimpled coupling band connected at its ends by 2-inch by 2-inch by 3/16-inch angles with 3-1/2 inch bolts is an acceptable coupler for joining annular to annular, helical to helical or helical to annular corrugated metal pipe in sizes up to 30-inches inclusive. The width of the band shall be a minimum of 12-inches. It is recommended that this band be restricted to pipe diameters of 30-inches maximum until industry presents substantiated data indicating that this coupler increased in width as necessary is equivalent to those recommended by AASHO M36 for larger diameters of pipe.

   Dimpled coupling bands shall be fabricated from flat galvanized steel sheets and shall have dimples impressed in circumferential rows to register with and engage the corrugations of the pipe to be joined. Each row shall contain at least seven (7) dimples so spaced to effectively engage all corrugations of the pipe ends. The dimples shall conform substantially to the shape of the corrugations of the pipe. There shall be two rows of dimples spaced 7-inches apart (see Figure 10).

7. Coupling bands may not be over two numerical gage thicknesses lighter than the sheet used for the pipe with a minimum thickness of 16 gage.

VI. DISCUSSION

The different types of coupling bands were evaluated by their ability to hold coupled lengths of corrugated metal pipe together when the coupled units were tested as a beam. Four foot lengths of 18 inch 16 gage coupled corrugated metal pipe were subjected to a third-point bend test in accordance with AASHO test method T97-60 (see Figure 1). A simple span of 90 inches was used. The coupling bands were located at the midspan of the resulting pipe beam in the area of pure bending. All coupling bands tested were made from 16 gage steel. The pipes were statically loaded in increments of 500 pounds until the ultimate strength of the coupled joint was reached. After each increment of load, the deflection at midspan and the slippage or the extension of the lower surface of the coupled pipe at the joint were recorded. Complete test results are shown in Tables 1 through 5 listed in the Appendix.

Test No. 1 consisted of a test of lengths of helical and annular corrugated pipe joined by a dimpled coupler (see Figure 10). The coupling band fitted the helical pipe rather poorly. The ultimate load of this system was 5400 pounds. After the completion of the test, it was noted that the helical pipe had a 2-inch by 1/2-inch corrugated profile whereas the band was fabricated to fit the 2-2/3 inch by 1/2-inch corrugation, thus explaining the poor fit and low ultimate load as compared to future tests of this type coupling band (see Table 4 for complete test results).

Test No. 2 consisted of a test of annular corrugated pipe joined by a 7-inch coupling band connected by angles which were spot welded to the band (see Figure 5). The angles were oriented on the bottom of the pipe. The ultimate load for this connected pipe was 3960 pounds. It was observed that one of the angles was moderately deformed, evidently from previous mishandling. Test No. 8 was a repeat test of this same coupler with the connecting angles oriented on the side of the pipe. This test was performed to determine if the location of the angles influenced the load carrying capability of the coupled pipe. Also intervening tests indicated that the ultimate load obtained was low by comparison to other tests. As on all repeat tests on a given coupler, the pipe was turned end for end to discount the influence of any distortion of the pipe from previous testing. The ultimate load for Test No. 8 was 3540 pounds. Close observation of the coupling band indicated that the deformed angle did not allow the coupler to seat properly (see Figure 6). See Table 1 for complete test results.

Test No. 9 was similar to Test No. 8 except that the coupling band was connected by angles which were riveted to the band, rather than spot welded. After reviewing the data from other tests, it was apparent that the distorted angle used on the band in Tests No. 2 and No. 8 had significantly affected the joint strength. The connection angle location for this test was on the side of the pipe. The pipe used was of riveted fabrication with the rivets oriented in a horizontal plane. The ultimate load for this connected pipe was 6910 pounds. To substantiate the results of this test, Test No. 11 was run; the only difference in this test was that the pipe rivets were located in a vertical plane. The ultimate load for Test No. 11 was 6700 pounds (see Table 1 and Table 2 for complete test results).

Test No. 3 consisted of a test of a 9-1/2 inch wide annularly corrugated coupling band connected at the ends by bolts through formed lugs (see Figure 9). The bolted connection was located at the bottom of the pipe. The ultimate load sustained was 6800 pounds. Test No. 6 was a repeat test with the bolts located on the side of the pipe. The ultimate load for this test was slightly higher at 7040 pounds. It was noted in Test No. 3 that one spot weld failed in one section of the pipe. Several welds failed in subsequent Test No. 6 (see Table 3 for complete test results).

Test No. 4 was a test of a 7-inch wide annularly corrugated band connected by bolts through formed lugs in the band (see Figure 7). The bolts were located on the bottom of the pipe. The pipe thus connected sustained an ultimate load of 7740 pounds. Test No. 7 was a proof test of this coupler with the bolts located on the side of the pipe. An ultimate load of 7800 pounds was recorded indicating that bolt location had little influence on the coupler performance.

Test No. 5 consisted of a test of helically corrugated pipe connected by a two piece 12-inch wide coupling band connected at the ends of the pieces by bolts through formed lugs (see Figure 3). The coupling band was able to develop the strength of the pipe in bending. An ultimate load of 8400 pounds was recorded when failure occurred at a pipe corrugation adjacent to one of the upper loading blocks. The coupler and the lengths of pipe remained intact (see Table 2 for complete test results).

Tests No. 10 and No. 12 were performed to investigate the pipe spot weld failures noted in Tests No. 3 and No. 6 and determine if these failures affected the joint strength of the coupling band. The coupling bands were the 9-1/2 inch formed lug type similar to those previously used. In both tests the bolted connection was located on the side of the pipe. In Test No. 10 the pipe spot welds were located in a horizontal plane; in Test No. 12 the welds were oriented in a vertical plane. The ultimate loads recorded for these tests were 7660 pounds and 6980 pounds respectively. No weld failures occurred in these tests or other tests except as noted, thus verifying that the pipe used in Tests No. 3 and No. 6 was defective and that the weld failure that occurred was an abnormal condition (see Table 3 and Table 4 for complete test results).

Test No. 13 consisted of a test of annularly corrugated metal pipe connected by a 14-inch wide universal or dimpled coupling band (see Figure 10). The band was connected at the ends by 2-inch by 2-inch by 3/16-inch angles joined by 3- 1/2-inch bolts. The pipe thus connected sustained an ultimate load of 8000 pounds. The pipe failed at the joint by the lower dimples slipping across the corrugations (see Figure 11--note impression of dimples on the pipe corrugations). Actual separation of the pipe did not occur in any of the tests on this type coupling band (see Table 5 for complete test results).

Test No. 14 was a test of two lengths of helically corrugated pipe connected by the coupling band used for Test No. 13. The ultimate load was 7860 pounds.

Test No. 15 consisted of a test of a length of annularly corrugated pipe connected to a length of helically corrugated pipe by the same coupler as used for the two previous tests. The ultimate load of this combination was 7600 pounds. For the three forementioned tests the coupling band used provided a good, tight fit. The band was easily installed regardless of the type of pipe connected.

Tensile tests on the dimpled coupling were not included in this investigation. It is believed that bending tests provide sufficient information with regards to the ability of a coupler to hold lengths of pipe together considering unequal settlement of foundation material. Information garnered from tensile tests would be applicable to overside drain installations, however. From a report submitted to us by the United States Steel Corporation (Ref. 2), a 24" coupled pipe pulled in tension and utilizing a dimpled coupler was able to sustain a load of 7500 pounds. From calculations on the forces imposed on a coupler used for a 24" overside drain installation, the maximum force that could be expected assuming a full flowing pipe without anchorage and reposing on a saturated 2:1 slope would be 2370 pounds for a 20 foot length of pipe. Based on this information it is not believed that a tensile test is necessary or would furnish meaningful information.

Test No. 16 consisted of a test of annularly corrugated metal pipe joined by a 7-inch wide coupling band connected by bolts through integral formed lugs. Previous tests on this coupling band indicate a superior joint strength as compared to the 7-inch wide band connected by angles. However due to the forming of the lugs for this band, which requires cutting of the band normal to the corrugations, very little sheet material remains between the lugs. There is concern that this weakened portion of the band may fail by overtightening of the connection bolts. To verify such a failure would reduce the joint strength, a test was performed with the material between lugs intentionally ruptured (see Figure 8). The ultimate strength of this coupled pipe was 5300 pounds which is 70% of the strength of the coupled pipe using the original undamaged coupler and 80% of the strength of the pipe coupled with the band connected by angles (see Table 6 for complete test results).

VII. REFERENCES

1. Faist, W. E., "A Report of Tests of Band Couplers for Riveted CMP and Lockseam CMP", April 1963.

2. Carskadden, P. S., "Evaluations of Dimpled and Corrugated Bands for Culvert Pipe Joints", United States Steel Corporation, Applied Research Laboratory.

VIII. APPENDIX

Table 1	Tests No. 2, 8, and 9
Table 2	Tests No. 11, 4, and 7
Table 3	Tests No. 3, 6, and 10
Table 4	Tests No. 12, 5, and 1
Table 5	Tests No. 13, 14, and 15
Table 6	Test No. 16
Figure 1	Coupled Pipe Subjected to Flexural Load Test.
Figure 2	Seven inch wide integral flange die formed coupling band used for helical pipe.
Figure 3	Twelve inch wide two piece coupling band with integral formed lug connections used for helical pipe.
Figure 4	Twelve inch wide coupling band with angles used for helical pipe.
Figure 5	Seven inch wide standard AASHO coupling band.
Figure 6	Seven inch wide standard AASHO coupling band showing deformed connection angle.
Figure 7	Seven inch wide coupling band with integral formed lug connections.
Figure 8	Seven inch wide coupling band with integral formed lug connections. Material between lugs intentionally ruptured. Photo taken after flexure test.
Figure 9	Nine and two thirds inch wide coupling band with integral formed lug connections.
Figure 10	Universal or dimpled coupling band 14 inches in width.
Figure 11	Universal coupling band after test. Note impression of dimples on the pipe corrugations.

TABLE 1

Test No.	2				8				9			
Type of CMP	Annular (Welded)				Annular (Welded)				Annular (Riveted)			
Type of Coupler	AASHO - Welded Angles				AASHO - Welded Angles				AASHO - Riveted Angles			
Width of Coupler	7" (One-Piece)				7" (One-Piece)				7" (One-Piece)			
Location of Connector	Bottom				Side				Side			
No. of Bolts	2-1/2"				2-1/2"				2-1/2"			
	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks
	500	0.08	0		500	0.06	0.02		500	0.11	0.04	
	1000	0.18	0		1000	0.16	0.03		1000	0.28	0.08	
	1500	0.27	0.05		1500	0.27	0.03		1500	0.43	0.14	
	2000	0.38	0.07		2000	0.38	0.06		2000	0.56	0.18	
	2500	0.50	0.13		2500	0.51	0.10		2500	0.68	0.20	
	3000	0.62	0.19		3000	0.65	0.16		3000	0.83	0.23	
	3500	0.76	0.30		3500	0.90	0.23		3500	0.98	0.31	
	3960			Sudden Failure Completely Separated	3540			Sudden Failure Completely Separated	4000	1.11	0.35	
									4500	1.26	0.40	
									5000	0.43	0.45	
									5500	1.61	0.55	
									6000	1.78	0.64	
									6500	2.04	0.74	
									6910			Failure
										1.23		Permanent Set

All pipe 16-gage, 18-inch diameter.

Unsupported span 90 inches.

TABLE 2

Test No.	11				4				7			
Type of CMP	Annular (Riveted)				Annular (Welded)				Annular (Welded)			
Type of Coupler	AASHO - Riveted Angles				Integral Formed Lug				Integral Formed Lug			
Width of Coupler	7" (One-Piece)				7" (One-Piece)				7" (One-Piece)			
Location of Connector	Side				Bottom				Side			
No. of Bolts	2-1/2"				2-1/2" Bolts With Washers				2-1/2" Bolts With Washers			
	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks
	500	0.09	0.03		500	0.10	0.01		500	0.07	0.04	
	1000	0.25	0.12		1000	0.22	0.02		1000	0.13	0.05	
	1500	0.38	0.21		1500	0.33	0.06		1500	0.22	0.08	
	2000	0.50	0.26		2000	0.43	0.10		2000	0.30	0.08	
	2500	0.63	0.31		2500	0.54	0.14		2500	0.39	0.12	
	3000	0.76	0.36		3000	0.64	0.17		3000	0.49	0.14	
	3500	0.88	0.43		3500	0.76	0.22		3500	0.61	0.17	
	4000	1.04	0.51		4000	0.87	0.26		4000	0.72	0.20	
	4500	1.18	0.58		4500	1.00	0.28		4500	0.84	0.22	
	5000	1.34	0.60		5000	1.12	0.33		5000	0.95	0.26	
	5500	1.49	0.73		5500	1.25	0.38		5500	1.07	0.29	
	6000	1.73	0.84		6000	0.42	0.43		6000	1.19	0.36	
	6500	2.07	1.00		6500	1.58	0.49		6500	1.33	0.42	
	6700	1.23		Failure Permanent Set	7000	1.77	0.57		7000	1.48	0.48	
					7500	2.00	0.67		7500	1.67	0.58	
					7740			Failure Separated	7800	0.81		Failure Permanent Set

All pipe 16-gage, 18-inch diameter.

Unsupported span 90 inches.

TABLE 3

Test No.	3				6				10			
Type of CMP	Annular (Welded)				Annular (Welded)				Annular (Welded)			
Type of Coupler	Integral Formed Lug				Integral Formed Lug				Integral Formed Lug			
Width of Coupler	9-1/2" (One-Piece)				9-1/2" (One-Piece)				9-1/2" (One-Piece)			
Location of Connector	Bottom				Side				Side			
No. of Bolts	2-1/2" Bolts With Washers				2-1/2" Bolts With Washers				2-1/2" Bolts With Washers			
	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks
	500	0.10	0.01		500	0.09	0		500	0.07	0	
	1000	0.18	0.07		1000	0.16	0		1000	0.15	0.02	
	1500	0.33	0.10		1500	0.25	0.02		1500	0.24	0.04	
	2000	0.47	0.10		2000	0.36	0.03		2000	0.31	0.06	
	2500	0.57	0.13		2500	0.48	0.13	Welds Began Breaking on one Pipe Section	2500	0.41	0.09	
	3000	0.68	0.20		3000	0.61	0.18		3000	0.50	0.11	
	3500	0.77	0.22		3500	0.74	0.24		3500	0.60	0.14	
	4000	0.85	0.23		4000	0.89	0.26		4000	0.71	0.16	
	4500	0.98	0.36	Pipe Section Weld Failed	4500	1.05	0.33		4500	0.82	0.19	
	5000	1.13	0.39		5000	1.20	0.36		5000	0.93	0.24	
	5500	1.23	0.41		5500	1.35	0.42		5500	1.05	0.26	
	6000	1.41	0.53		6000	1.56	0.45		6000	1.18	0.28	
	6500	1.63	0.59		6500	1.79	0.45		6500	1.35	0.37	
	6800			Sudden Failure Completely Separated	7000	2.19	0.60		7000	1.52	0.43	
					7040			Failure	7500	1.74	0.52	
						1.02		Permanent Set	7660			Failure
										0.90		Permanent Set

All pipe 16-gage 18-inch diameter.

Unsupported span 90 inches.

Test No.	12				5				1			
Type of CMP	Annular (Welded)				Helical (Lock Seam)				Annular to Helical			
Type of Coupler	Integral Formed Lug				Integral Formed Lug				Dimpled (Angle)			
Width of Coupler	9-1/2" (One-Piece)				12" (Two-Piece)				14" (One-Piece)			
Location of Connector	Side				Bottom and Top				Bottom			
No. of Bolts	2-1/2" Bolts With Washers				2-1/2" Bolts With Washers				3-1/2" Bolts			
	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks
	500	0.15	0.05		500	0.13	0		500	0.38		
	1000	0.29	0.12		1000	0.27	0.04		1000	0.71	0.50	
	1500	0.39	0.15		1500	0.41	0.09		1500	0.93		
	2000	0.49	0.17		2000	0.55	0.17		2000	1.13	0.80	
	2500	0.59	0.19		2500	0.72	0.31		2500	1.24		
	3000	0.69	0.23		3000	0.88	0.37		3000	1.38	0.85	
	3500	0.79	0.27		3500	1.02	0.48		3500	1.56		
	4000	0.91	0.32		4000	1.16	0.49		4000	1.75	1.05	
	4500	1.02	0.35		4500	1.28	0.47		4500	1.94	1.20	
	5000	1.15	0.39		5000	1.40	0.52		5000	2.15	1.35	
	5500	1.29	0.45		5500	1.52	0.56		5400			Failure
	6000	1.46	0.48		6000	1.66	0.60			2.45		Permanent Set
	6500	1.63	0.57		6500	1.83	0.69					
	6980			Failure	7000	2.00	0.74					
		0.99		Permanent Set	7500	2.20	0.77					
					8000	2.46	0.80					
					8400	3.13	0.84	Corrugation Failed				
						2.14		Connection Intact Permanent Set				

All pipe 16-gage 18-inch diameter

Unsupported span 90 inches.

NOTE: Helical pipe incorrectly furnished with 2" x 1/2" corrugation.

TABLE 4

TABLE 5

Test No.	13				14				15			
Type of CMP	Annular (Riveted)				Helical				Annular to Helical			
Type of Coupler	Dimpled (Angle)				Dimpled				Dimpled			
Width of Coupler	14" (One-Piece)				14" (One Piece)				14" (One-Piece)			
Location of Connector	Bottom				Bottom				Bottom			
No. of Bolts	3-1/2"				3-1/2"				3-1/2"			
	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks	Load	Defl.	Ext.	Remarks
	500	0.06	0.00		500	0.06	0.00		500	0.08	0.05	
	1000	0.13	0.02		1000	0.13	0.00		1000	0.20	0.10	
	1500	0.24	0.04		1500	0.39	0.17		1500	0.39	0.20	
	2000	0.37	0.11		2000	0.58	0.29		2000	0.58	0.30	
	2500	0.49	0.18		2500	0.82	0.47		2500	0.76	0.41	
	3000	0.63	0.23		3000	0.96	0.56		3000	0.97	0.50	
	3500	0.81	0.33		3500	1.10	0.63		3500	1.14	0.55	
	4000	0.93	0.39		4000	1.27	0.67		4000	1.37	0.65	
	4500	1.08	0.47		4500	1.36	0.78		4500	1.58	0.75	
	5000	1.25	0.59		5000	1.58	0.86		5000	1.82	0.85	
	5500	1.46	0.69		5500	1.82	1.02		5500	2.10	1.00	
	6000	1.77	0.85	Dimples Began To Slip Across Corrugations	6000	2.00	1.06		6000	2.37	1.20	
	6500	2.12	1.07		6500	2.26	1.20		6500	2.71	1.40	
	7000	2.50	1.27		7000	2.58		Dimples Began To Slip Across Corrugations	7000	3.05	1.55	
	7500	3.00	1.72		7500	3.14			7500	3.65	1.90	
	8000	3.15	1.97	Failed	7860				7600			Failed
		2.83		Permanent Set		3.41		Permanent Set		3.57		Permanent Set

All pipe 16-gage 18-inch diameter.

Unsupported span 90 inches.

TABLE 6

Test No.	16 (Damaged Coupler)		
Type of CMP	Annular (Welded)		
Type of Coupler	Integral Formed Lug		
Width of Coupler	7"		
No. of Bolts	2-1/2" Bolts With Washers Connector on Bottom		
	Load (Lbs.)	Deflection (Inches)	*Extension (Inches)
	500	0.28	0.19
	1000	0.50	0.29
	1500	0.68	0.38
	2000	0.85	0.47
	2500	1.00	0.54
	3000	1.14	0.60
	3500	1.25	0.64
	4000	1.40	0.69
	4500	1.55	0.73
	5000	1.72	0.77
	5300 Failure		
	Permanent Set	2.40	1.89

Unsupported Span = 90"

Third-Point Loading

* Extension of coupled joint at bottom of CMP.

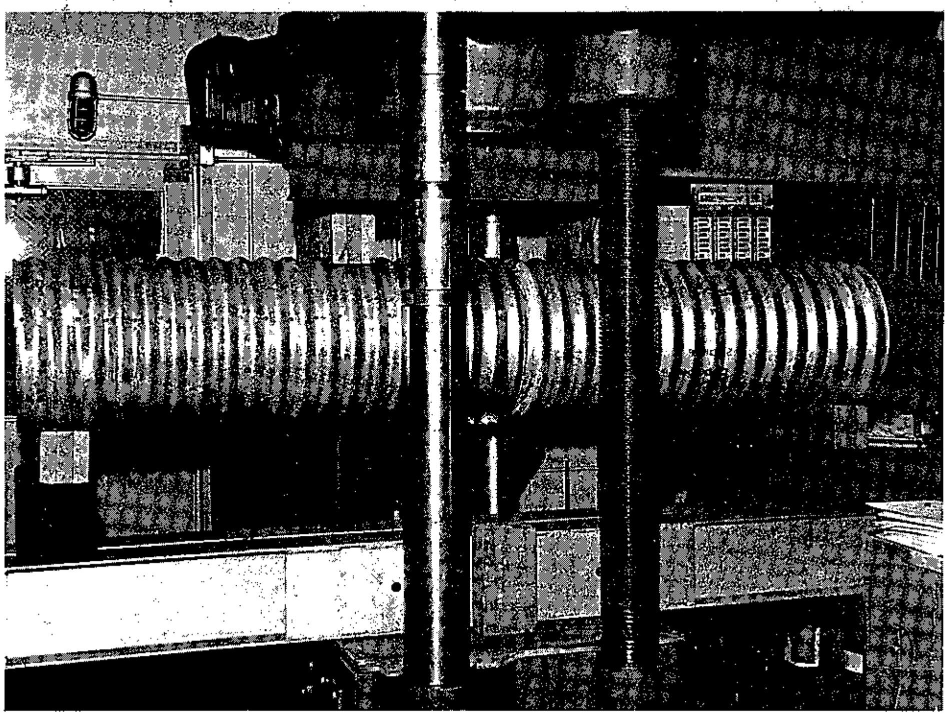

Figure 1

Coupled Pipe Subjected to Flexural Load Test.

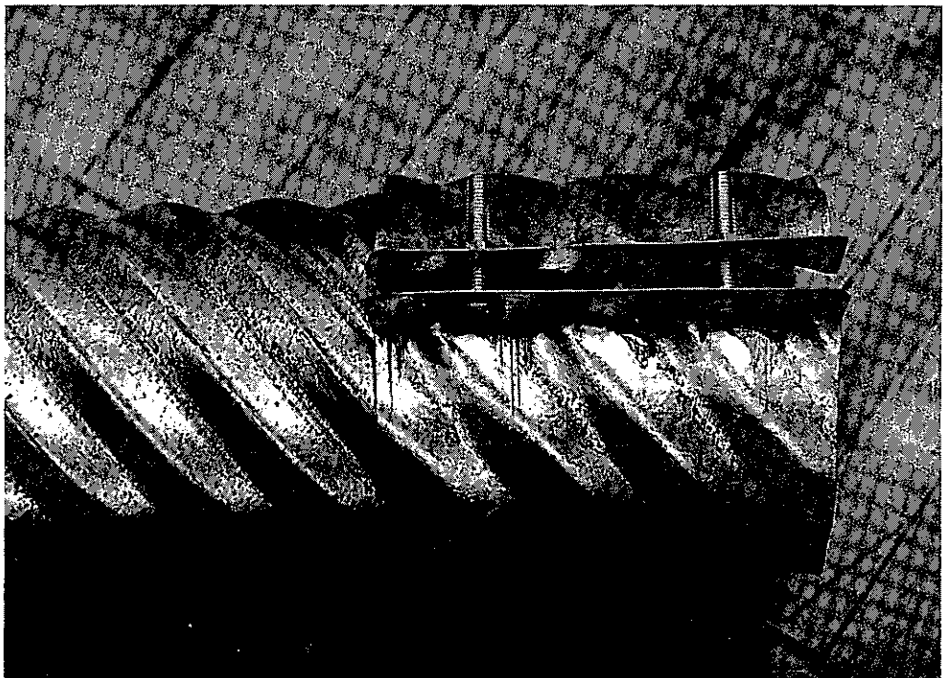

Figure 2

Seven Inch Wide Integral Flange Die Formed Coupling Band Used for Helical Pipe.

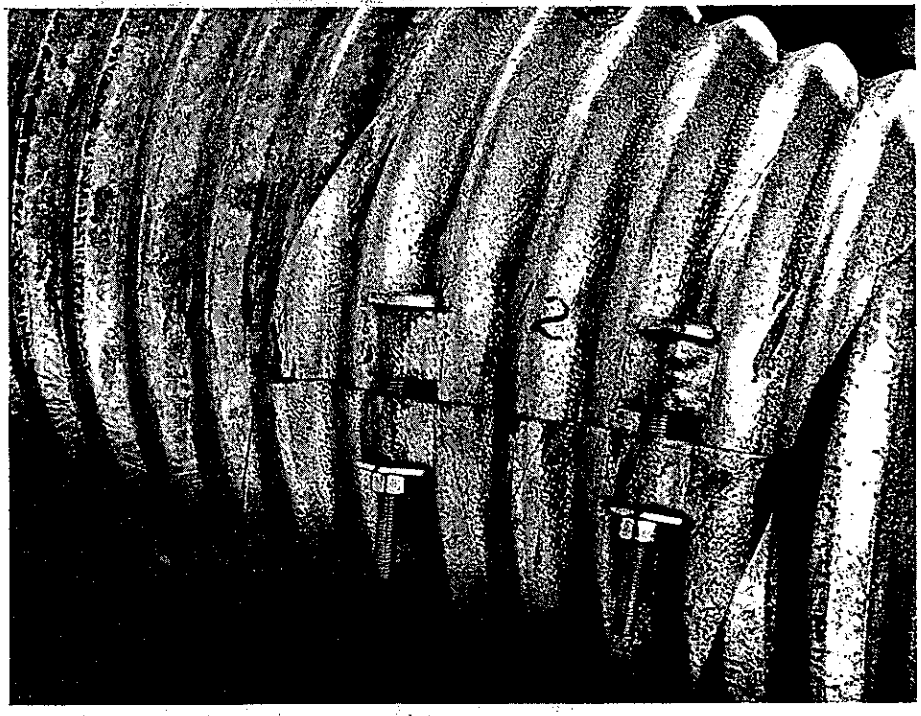

Figure 3

Twelve Inch Wide Two Piece Coupling Band with Integral Formed Lug Connections Used for Helical Pipe.

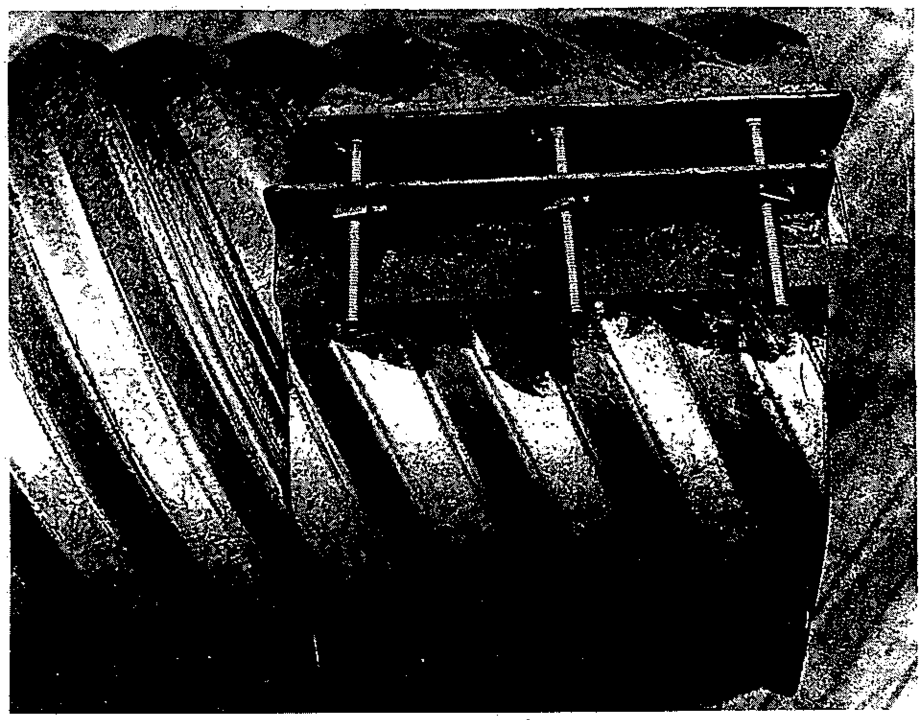

Figure 4

Twelve Inch Wide Coupling Band with Angles Used for Helical Pipe.

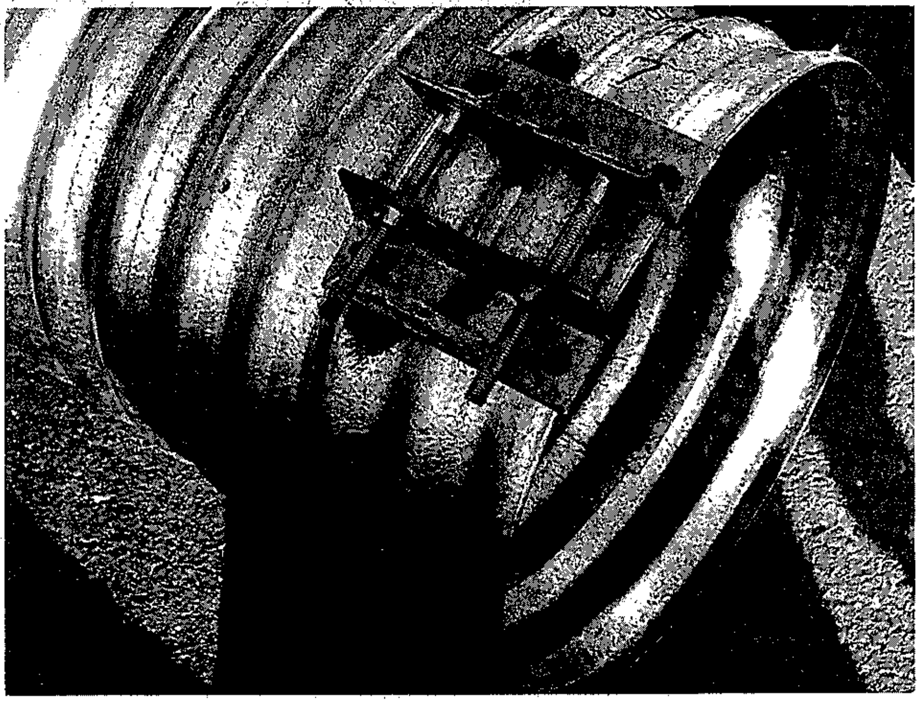

Figure 5

Seven Inch Wide Standard AASHO Coupling Band.

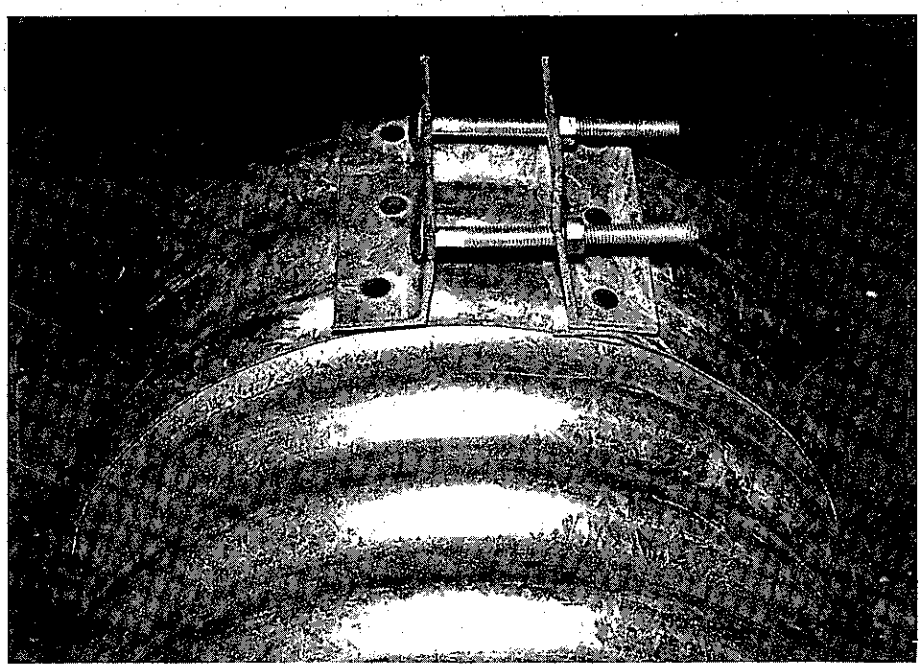

Figure 6

Seven Inch Wide Standard AASHO Coupling Band Showing Deformed Connection Angle.

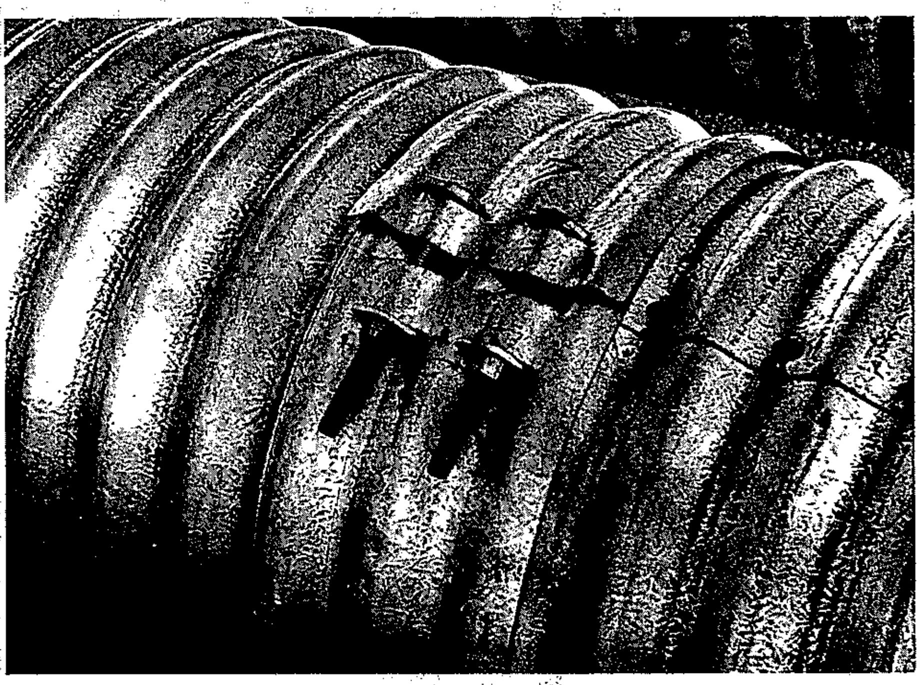

Figure 7

Seven Inch Wide Coupling Band with
Integral Formed Lug Connections.

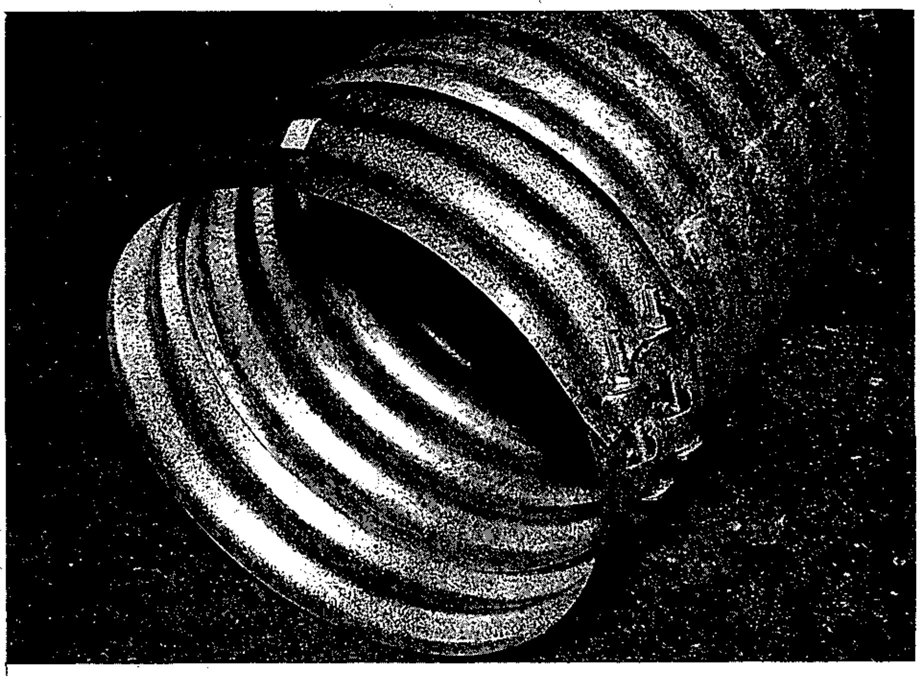

Figure 8

Seven Inch Wide Coupling Band with
Integral Formed Lug Connections.
Material Between Lugs Intentionally
Ruptured. Photo Taken After Flexure Test.

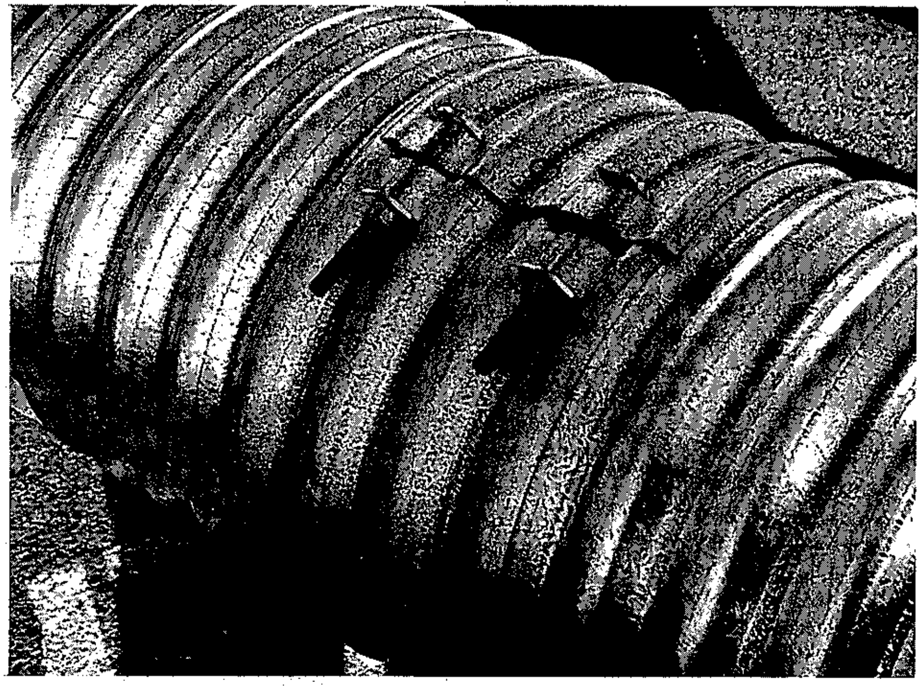

Figure 9

Nine and Two Thirds Inch Wide Coupling Band with Integral Formed Lug Connections.

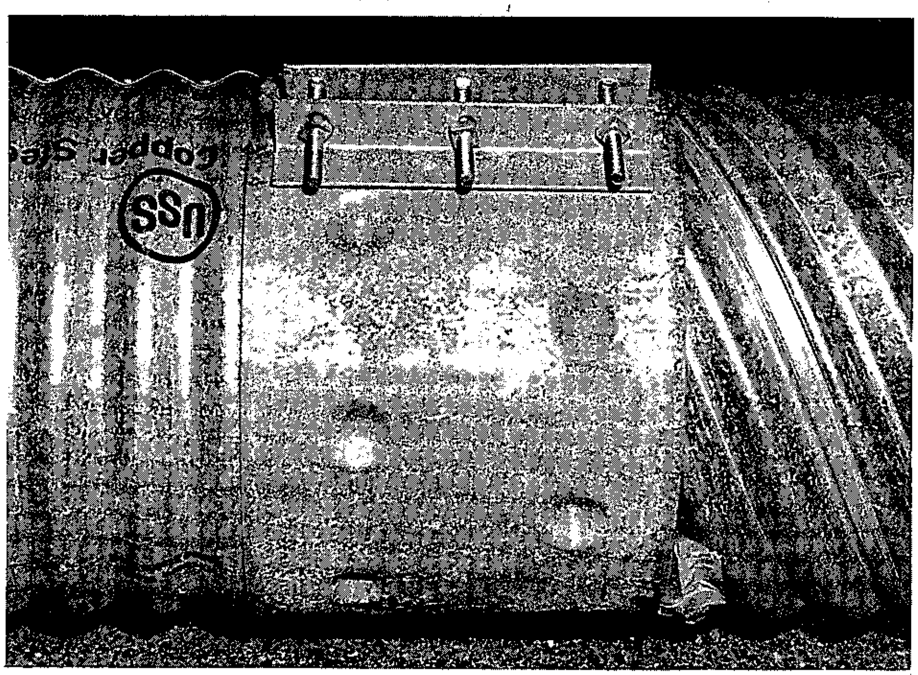

Figure 10

Universal or Dimpled Coupling Band Fourteen Inches in Width.

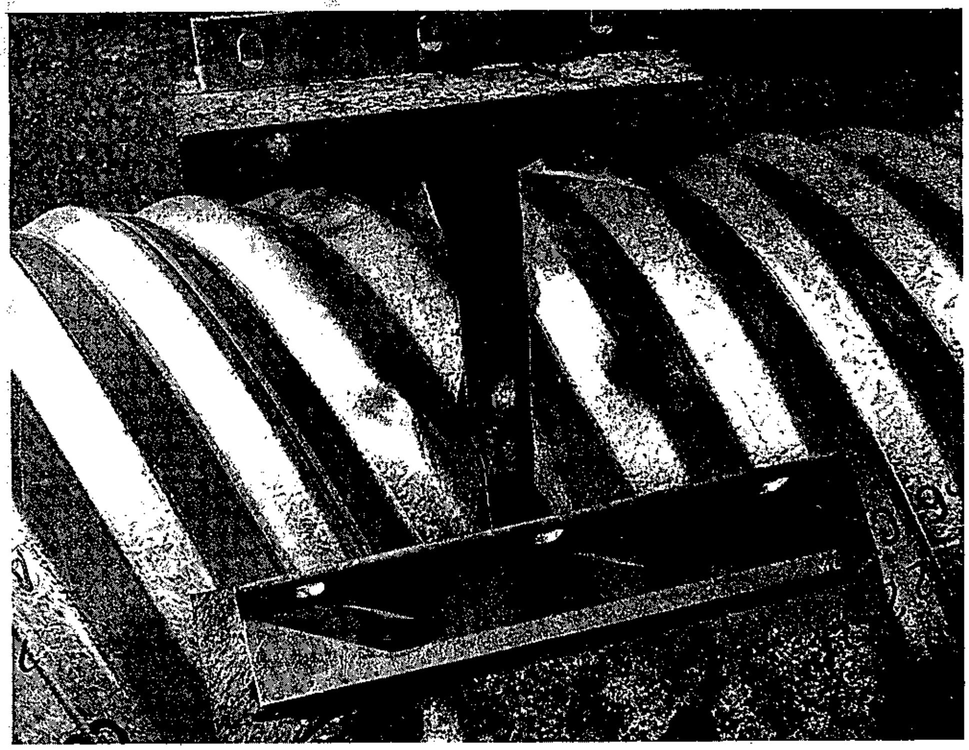

Figure 11

Universal Coupling Band After Test.
Note Impression of Dimples on the
Pipe Corrugations.